

be a major issue in encapsulation of, for example, a phosphor for LED applications because encapsulant cracking can cause wires on an LED to debond.

5 LED manufacturers currently are using epoxy resins or siloxane materials in such encapsulant applications. The epoxy resins now in use are organic polymeric materials and they have a tendency to yellow upon exposure to UV light. The siloxane materials used are transparent to UV light and can resist the UV light exposure from the LED. However, these siloxane materials are normally very soft and can be damaged very easily during manufacturing, shipping and/or application. In addition, 10 these siloxane materials cannot protect moisture sensitive dopants. A non-hydrolytic sol-gel spin-on glass material can be a good alternative for both of these systems

15 The prior art reveals there is a need for improving material characteristics for LED encapsulation applications. The major focus of these prior art patents involves using an epoxy or siloxane material as an encapsulant in such LED applications.

U.S. Patent No. 6,204,523 describes a method for encapsulating a phosphor in an LED using a silicone material. The LED can emit light of wavelength green (570 nm) to near UV (350 nm) wavelength range. This patent claims that the silicon material does 20 not yellow upon extended exposure to UV light. It is also disclosed it is then necessary to use a resilient soft core in the vicinity of the LED chip to prevent damage caused by mechanical stress to the LED chip or its wire leads. A harder shell is also utilized on the exterior to provide better protection and integrity to the LED. Different dopants can be used in these encapsulant materials. The silicon coated LED 25 substantially maintains its light transmission when exposed to a temperature between 85 degrees Celsius (°C) and 100 °C and a relative humidity of 85%.

The published prior art documents the use of a sol-gel material resulting from the de-alcoholation of an alkoxy silane. The process temperature is between 80 °C and 30 150 °C. The fluorescent material is admixed with a solution of this sol-gel material, which is then applied and heated to produce a glass-like body. Two different dopants

$R_1$  = Ethyl, propyl, another C<sub>1</sub> to C<sub>8</sub> Alkyl, Halogenated C<sub>1</sub> to C<sub>8</sub> Alkyl, Phenyl and Halogenated Phenyl

$R_2$  = Methyl, Ethyl or another C<sub>1</sub> to C<sub>8</sub> Alkyl

X, Y = Si, Ge, Ti or Sn

5 Z = Alkyl, Phenyl, Substituted phenyl

Wherein in Formulas II, III and IV:

$R$  = Methacryloxyalkyl, Acryloxyalkyl or Glycidyloxyalkyl

10  $R_1$  = Phenyl or Substituted Phenyl; Ethyl, Propyl or another C<sub>1</sub> to C<sub>8</sub> Alkyl; or Trifluoroalkyl such as Trifluoropropyl

$R_2$  = Methyl, Ethyl or another C<sub>1</sub> to C<sub>8</sub> Alkyl

X, Y = Si, Ge, Ti or Sn

Z = Alkyl, Phenyl, substituted Phenyl

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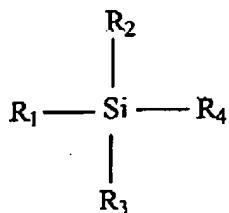
The subject SOG material is preferably produced in a non-aqueous media and may be

heat cured or UV light cured, depending upon the exact structure of the material. The

20 SOG material of the present invention is preferably produced from an alkyl substituted

trialkoxysilane or a dialkyl substituted dialkoxysilane, wherein the alkyl group has 1 to

8 methyl groups, represented by the formula:



$\text{R}_1$ = Alkyl (C<sub>1</sub> to C<sub>8</sub>), Methacryloxypropyl, Acryloxy, Glycidyloxyalkyl

$\text{R}_2$ = Alkyl, Substituted Alkyl, Phneyl, Substituted phenyl, Methoxy, Ethoxy

$\text{R}_3$ = Methyl, Methoxy, Ethoxy, Alkoxy

$\text{R}_4$ = Methoxy, Ethoxy, alkoxy

The alkyl group may, for example, be replaced with a methacryloxypropyl, acryloxypropyl, or epoxy moiety, which improves the suitability of this SOG material for UV printing and patterning. The trialkoxysilane may have one or more (preferably 1 to 3) C<sub>1</sub> to C<sub>8</sub> alkyl, methacryloxypropyl and/or alkoxy groups on the same molecule. This provides a preferred SOG material with a higher degree of flexibility and improved patterning when using UV illumination. Reducing the number of alkoxy groups from 3 to 2 also reduces the cross-link density of the present SOG material and also improves its material flexibility, which allows this material to further tolerate the stress cause by extreme cold, heat, or mechanical shock.

A process is provided for producing the subject sol-gel spin-on glass (SOG) material of the present invention by: reacting an alkyl substituted trialkoxysilane or a dialkyl substituted dialkoxy silane with a silane diol. Said alkyl group has from 1 to 8 carbon atoms. The silane diol is preferably a diphenylsilanediol, a 1,3-Bis (3-hydroxypropyl) tetramethoxysilane, a 1,3-Bis (4-hydroxybutyl) tetramethylsilane, a fluorinated silane diol, or a mixture of one or more of these silane diols. The alkyl group may be replaced with a methacryloxypropyl, acryloxypropyl, or epoxy moiety. The trialkoxysilane or dialkoxy silane may have one or more (preferably 1 to 3) C<sub>1</sub> to C<sub>8</sub> alkyl, methacryloxypropyl and/or alkoxy groups on the same molecule. The process may further comprise adding an inorganic or organic dopant, wherein the dopant preferably comprises a phosphor dopant (such as a YAG base phosphor or a moisture

sensitive phosphor) nano-particles, or an organic material such as an organic dye or a metal complex.

A process is also provided for patterning the non-aqueous sol-gel spin-on glass (SOG) 5 material of the present invention by: a) coating a substrate with the spin-on glass material; b) exposing the coated substrate of step a) to UV illumination in a desired pattern; c) post-exposure baking the coated substrate of step b) at a temperature from 100 °C to 120 °C for 30 to 60 minutes; d) cooling the coated substrate of step c) to room temperature; e) removing the non-exposed areas of the coating on the coated 10 substrate of step d); f) drying the coated substrate of step e); g) hard baking the coated substrate of step f) at a temperature from 120 °C and 150 °C for 1 to 3 hours.

The process may further comprise adding a UV light blocking material and/or an 15 oxygen scavenger, a light-scattering material, or a coupling agent, wherein the coupling agent is preferably a dibutoxyaluminoxytriethoxysilane, a mixture of zirconium isopropoxide and methacrylic acid, or another transition metal propoxide. The process may also comprise the reaction of an alkoxy silane with an organic diol in a non-aqueous medium in the presence of a catalyst, wherein the catalyst is preferably 20 a tin catalyst (such as dibutyltin diluarate), titanium isopropoxide, acetic acid or trifluororoacetic acid. The process may further comprising adding a coupling agent, wherein the coupling agent is preferably a dibutoxyaluminoxytriethoxysilane, a mixture of zirconium isopropoxide and methacrylic acid, or another transition metal propoxide.

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#### BRIEF DESCRIPTION OF THE DRAWINGS AND TABLES

Figure 1 illustrates the structure of a silane molecule of the present invention with different related substituents such as a mono-alkyl, dialkyl, allyl, acryloxypropyl, 30 methacryloxypropyl, or an epoxy group.